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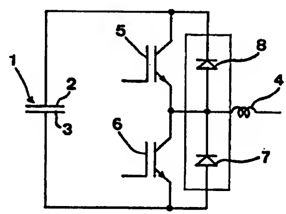
(54) Title: CONVERTER CIRCUIT, CIRCUITRY HAVING AT LEAST ONE SWITCHING DEVICE AND CIRCUIT MODULE

(57) Abstract

A converter circuit has at least one switching device (5, 6) and a diode (7, 8) arranged to be conducting when the device is turned off and reverse biased when the device is turned on. Said diode is made of SiC.



Converter circuit, circuitry having at least one switching device and circuit module

TECHNICAL FIELD OF THE INVENTION AND PRIOR ART

The present invention relates to a converter circuit having at least one switching device and a diode arranged to be conducting when the device is turned off and reverse biased when the device is turned on as well as a circuitry and a module according to the independent claims therefor.

The invention is particularly, but not exclusively, occupied with the problems arising in converter circuits used for high voltage applications and it is directed to all types of such converter circuits, such as inverters converting a direct-current voltage to an alternating voltage, rectifiers converting an alternating voltage into a direct-current voltage and direct current converters converting a direct-current voltage into a higher or lower direct-current voltage.

Such converter circuits are connected to a load, for instance an electric motor, which is supplied with a certain voltage obtained by the converter circuit. A diode in this circuit is used as a so called freewheeling diode to improve the capability of the converter circuit to produce a voltage with the characteristics aimed at primarily by smoothing out the abrupt changes in the circuit due to switchings of the switching device and to protect the latter by taking care of the conduction of the current which said load is calling for when the switching device is turned off.

Such diodes used until now in such converter circuits and mostly made of Si have some disadvantages causing severe problems. In fact these diodes are the devices of such circuits which limit the performance of the entire circuit, mainly because of the inherent limitations in switching performance with large switching losses and risk of destruction due to dynamic avalange. At higher voltages diffused pn-junction diodes having high switching losses are used.

The main problem arises when said switching device of the circuit is turned on and the diode gets reverse biased. The diodes of this type have a comparatively high reverse recovery charge, i.e. a high amount of excess electrons and holes are stored within the n- and p-regions of the device, and this charge has to be withdrawn when the diode has been reverse biased, which means that a reverse current appreciably higher than the saturation or leakage current in the turned-off state of the diode will pass therethrough for some time. This will result in high switching losses and heat dissipation in the diode, since the voltage over the diode during this reverse current will be high after the turning on of the switching device and the turning off of the diode. Also this reverse current through the diode causes extra turn-on losses within the switching device. Furthermore, the diodes of Si gets unstable already at comparatively low temperatures. The quality of the current obtained by such a converter circuit will increase with an increasing frequency of the switching of said switching device, but the switching losses are also increasing with increasing switching frequency, so that the frequency of the switching has to be kept at such a low level that the devices of the converter circuit will not be destroyed due to overheating. Furthermore, the diode may be destroyed due to dynamic avalanche when there are excess charge carriers left in the diode when the reverse blocking voltage over the diode has become high. Thus, there usually is a need to reduce the turn-on speed of the switching device, which is not good for the optimal performance of the circuit. There is also a problem, but mostly not that accentuated, when the switching device is turned off. The diode will then be turned on with a very fast increasing current. The large Si di-

odes used as high voltage power devices will namely directly after the turning on of the diode before the creation of a required amount of excess charge carriers therein have a high resistance resulting in a high voltage, a phenomena called forward recovery.This voltage overshoot can have negative effects on the power electronic circuit, create unwanted losses and it can also stress the diode and limit the life time of the diode influencing the reliability of the entire converter circuit. This will also cause voltage overshoots for the switching device. When the diode is used as a snubber diode this forward recovery overshoot is often the limiting factor for the swithcing devices, especially if it is a GTO.

SUMMARY OF THE INVENTION

The object of the present invention is to provide a converter circuit of the type defined in the introduction, in which the disadvantages mentioned above are drastically reduced with respect to such converter circuits already known.

This object is in accordance with the invention obtained by making said diode of SiC.

SiC has a high thermal stability due to a large band gap energy, such that devices fabricated from SiC are able to operate at high temperatures, namely up to 1 000 K. Furthermore, it has a high thermal conductivity, so that SiC devices may be arranged at a high density. SiC also has approximately ten times higher breakdown field than Si, so that it is well suited as a material for high power devices operating under conditions where high voltages may occur in the blocking state of a device, and a diode in a converter circuit in accordance with the invention having to hold a certain voltage in the blocking state thereof may be made much thinner than a corresponding diode of Si. This means in the present case that when the switching device in the converter circuit according to the invention is turned on there will in the case of a pn- or pin-diode be a very low reverse recovery charge in the diode resulting in a short re-

verse recovery time and much lower switching losses in the diode compared with diodes of Si. If said diode of SiC is arranged to alone take care of substantially all the current to be led to or from the load connected to the circuit not only the switching losses in the diode are drastically reduced, but also the heat energy generation in the switching device upon turning on thereof will be lower because of the reduced recovery current through the diode, which is led through the switching device and added to the turn-on current therethrough. Accordingly, less heat is generated in the circuit in the form of switching losses, which means that the components thereof will be less excerted to stresses at a given switching frequency, so that it will be possible to benefit from this advantage and keep the frequency just as high as in the prior art devices or increasing the frequency and by that the operation performance of said circuit. Furthermore, the much lower reverse recovery charge in the diode will considerably raise the margins to dynamic avalange therein.

When the switching device in a converter circuit according to the invention is turned off the SiC diode being much thinner than the Si diode will in the case of a pn- or pin-diode, turn on rapidly without any voltage peak, i. e. it has a much lower forward recovery, which gives rise to less disturbances in the power electronic circuit as well as lower power losses at turn-on of the diode.

The inventional idea of using SiC as material for a diode according to the introduction also makes a type of diode hitherto excluded for high voltage use but now very advantageous for solving the problems discussed in the introduction available for this type of converter circuits, namely the Schottky diode. The Schottky diodes known until now and mostly made of Si were never a realistic option as diodes in different converter circuits for the following reasons. They may not hold higher than one or two hundred volts in the reverse blocking state before the reverse leakage becomes a problem. Increasing the breakdown voltage of such a Schottky diode by making the low doped region adjacent to the metal very

thick will in the forward conducting state cause high losses since a Schottky diode function as a majority carrier conductor and said low doped region will function as a resistor. However, SiC has, as mentioned above, an approximately ten times higher breakdown field than Si, so that a Schottky diode of SiC may be made much thinner and may still hold voltages in the KV-range in the reverse blocking state. This in combination with the material dependent possibility to have a higher doping in SiC than in Si will reduce the resistance of such a diode in the forward conducting state to a well acceptable level. Thus, it will be possible to benefit from the other charactheristics of a Schottky diode making it well suited for this use in converter circuits, namely that there are due to primarily majority carrier conduction no real reverse recovery behaviour on turning off and forward voltage overshoot on turning on. Thus, the invention also comprises Schottky diodes made of SiC when it is spoken about diodes of SiC.

According to a preferred embodiment of the invention said diode of SiC is arranged to upon turning said switching device off alone take care of substantially all the current to be conducted one of a) to and b) from a load connected to the circuit and fed through said switching device in the turned on state thereof. In this case no other diode is required for taking care of substantial portions of the current led through the said switching device in the turned on state thereof, so that the disadvantages discussed above in the prior art converter circuit will not arise, and it will be possible to really benefit from the advantages of providing a diode of SiC in accordance with the invention.

According to another preferred embodiment of the invention the switching device is made of SiC, and it comprises a chip into which both the diode and the switching device are integrated. This will reduce the production steps and costs of the circuit.

According to another preferred embodiment of the invention the circuit is an inverter circuit and it comprises a second diode of SiC

connected antiparallel to said first mentioned switching device and a second switching device connected anti-parallel to the first mentioned diode, and one of a) said first switching device and said first diode and b) said second switching device and said second diode are arranged to take care of the supply of current to and the other from said load. By using the two diodes of SiC in such an inverter circuit it will be possible to invert the direct-current voltage to an alternating voltage while obtaining improved circuit performances according to the discussion above.

According to a further preferred embodiment of the invention the switching device is a gate turn-off thyristor, and said SiC diode is a snubber diode arranged in a branch connected in parallel with said switching device and also including a capacitor connected in series with the diode and arranged to be charged when the switching device is turned off and discharged when the switching device is turned on. It is essential that said snubber diode starts to conduct the current immediately upon turning off the thyristor for protecting the thyristor against destruction, and this will be possible thanks to that the diode of SiC may be made much thinner than a corresponding diode of Si. Furthermore, it is possible that the thyristor is turned on again before the current and the charge carriers have completely disappeared from the snubber diode, which means that it will be reversed biased and the same reverse recovery problem with high switching losses and a risk of dynamic avalange would arise would the diode be made of Si instead of SiC.

The invention also comprises a circuitry having at least one switching device and a first diode arranged to be forward biased and conducting when the device switches in one direction, and this circuitry has a second diode of SiC connected in parallel with said first diode and designed to instantaneously upon said switching take care of the major portion of the current through the two diodes, said portion decreasing with time and being in the steady conducting state a minor portion of the current conducted through the two diodes. Thanks to the arrangement of the diode of SiC in parallel

with the first diode the problems with negative effects in the power electronic circuit, unwanted losses and stresses excerted on said first diode and causing a limitation of the lifetime thereof will be solved. The diode of SiC may be made much thinner than said first diode, if this is made of silicon, so that it will turn on much faster with a very small forward recovery voltage and the voltage overshoot over said first diode will be considerably reduced thus solving the problems last mentioned. When the circuitry is in the steady conducting state the major portion of the current will be conducted through said first diode, so that the second diode of SiC may be made with a very small area. Such a small area of said second diode will nevertheless be able to reduce the voltage overshoot at turn on significantly, since the specific differential resistance at turn on of a SiC power diode will be much lower than in the corresponding SI diode.

The invention also comprises a device module comprising several switching devices and at least one diode of SiC arranged in a closed casing having terminals for connection thereof to an electric circuit. A diode of SiC used in a device module will owing to the characteristics of SiC give rise to lower heat dissipation of said devices as compared to if the diode is made of silicon, making it possible to have a simpler cooling arrangement and also to arrange the devices at a higher density within the module.

According to a preferred embodiment of the invention such a module is designed to be arranged in a converter circuit, it has switching devices connected in parallel and at least one SiC diode connected antiparallel to the switching devices, and the gates of the switching devices are connected in groups. Such a module will be advantageously used as a part of a converter circuit, where each switching device will take care of a portion of the current to be conducted to or from the load and the SiC diodes may be used for solving the problems arising when the switching devices are turned on and off in the way discussed above. Thanks to the use of diodes of SiC such a module may have lower losses and heat dissipation

than if the diode were made of silicon so that it would be possible to make it very compact without any risk of overheating and damage of the components thereof.

Further preferred features and advantages of the invention will appear from the other dependent claims and the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

With reference to the appended drawing, below follows a specific description of preferred embodiments of the invention cited as examples.

In the drawings:

Fig 1 is a circuit diagram of a converter circuit according to a first preferred embodiment of the invention,

Fig 2 is a circuit diagram of a converter circuit according to a second preferred embodiment of the invention,

Fig 3 illustrates a third preferred embodiment of the invention,

Fig 4 is a circuit diagram of a part of a converter circuit according to a fourth preferred embodiment of the invention, and

Fig 5 is a schematic, partially sectioned view of a module according to a preferred embodiment of the invention constructed in accordance with Fig. 4.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

A circuit diagram of a converter circuit in the form of an inverter circuit according to a preferred embodiment of the invention is shown in Fig. 1. More exactly, the circuit shown in Fig. 1 is arranged to drive one phase, i.e. constitute one leg, of a e.g. three-phase

power supply to a load. The circuit comprises a direct-current voltage power supply 1 with a positive and a negative electrode 2 and 3, respectively. The direct-current voltage from the power supply 1 has to be inverted to an alternating voltage by the inverter circuit for driving one phase of a load 4 here indicated by an inductance. The circuit comprises a first switching device 5 here indicated by an IGBT, i.e. an Insulated Gate Bipolar Transistor, a second switching device 6 in the form of another IGBT connected in series therewith, a first diode 7 of SiC connected in series with the first switching device 5 and anti-parallel to the second switching device 6 as well as a second diode 8 of SiC connected in series with the parallel connection of the first diode 7 and the second switching device 6 and anti-parallel to the first switching device 5. The IGBTs may be replaced by other BiMOS switching devices, e.g. MOS Controlled Thyristors (MCT). The two diodes 7 and 8 are in this case high voltage power diodes with the function as so called free wheeling diodes. The function of the inverter circuit is as follows: During the first positive half of a period of the alternating voltage created by the circuit for the load 4 the first switching device 5 is turned on and off with a high frequency. When the switching device 5 is in the conducting state the voltage drop thereover is low and the main part of the voltage drop of the power supply will be over the second diode 7 thus being in the reverse blocking state. The voltages over the IGBT 5 and the diode 7 may for instance be a few volts and one or a few kV, respectively. The current from the IGBT 5 is led to the load 4. When the IGBT 5 is turned off the load 4 will call for the same current as before because of the inductance of the load and the diode 7 will be turned on with the same dI/dt as for the turning off of the IGBT 5. To keep the switching losses low it is thereby desired to obtain a rapid turn-off of the IGBT, which accordingly will result in a rapid current increase through the diode 7. Since the diode 7 is made of SiC it may be thin and still have a breakdown field being high enough. Thus, the diode 7 will be turned on rapidly without any voltage peak, so that there will be no disturbances in the circuit and the losses therein will be very small. The current to the load 4 will when the IGBT 5 is completely turned

off be supplied through the diode 7. When the IGBT 5 is turned on again the diode 7 will be turned off with the same dI/dt as the IGBT 5 is turned on. When the IGBT 5 has been completely turned on the voltage thereacross will be low and the main voltage, i.e. one or a few kV will reverse biasing the diode 7 with a voltage thus being high. The reverse recovery charge in the form of excess electrons and holes present in the diode 7 will be led through the diode in the reverse direction thereof creating a switching loss in the diode as well as increasing the turn-on switching loss in the IGBT 5, since this current is added to the very turn-on current through the IGBT 5. However, these losses are in the present case very low, since the SiC diode will have a very low reverse recovery charge in comparison with for instance corresponding Si diodes. Thus, the losses in the diode 7 as well as in the IGBT 5 will be drastically reduced. Accordingly, switching may be carried out at a higher frequency without any higher losses than when using a Si diode and thus the performance of the circuit be improved. The switching of the IGBT 5 during said half period will take place many times in small time increments of the half period. For creating the second negative half period of the alternating voltage supply to the load 4 the second IGBT 6 is turned on and off resulting in that the current is drawn from the load 4 to the IGBT 6 and the second diode 8 alternatingly. The behaviour of the second IGBT 6 and the second diode 8 will be the same upon turning on and off as discussed above for the first IGBT 5 and the first diode 7.

The circuit diagram of Fig. 2 illustrates an inverter circuit according to a second preferred embodiment of the invention with a load 4', a first switching device 5' in the form of a GTO, i. e a Gate Turn-Off Thyristor, a first free wheeling diode 7', which may be of Si, SiC or another suitable material, a second switching device 6' in the form of a GTO and a second free wheeling diode 8', which may be of Si, SiC or another suitable material. This circuit is arranged to invert a direct-current voltage in the same way as the circuit according to Fig. 1 with the diodes 7' and 8' functioning in the same way upon turning on and off of the GTOs 5' and 6'. This circuit also comprises

a so called snubber diode 9' and 10' made of SiC connected in parallel with the GTO 5' and 6', respectively. Each snubber diode is connected in series with a capacitor 11', 12'. A branch connected parallel to each GTO also comprises a parastic stray inductance and a resistor 13', 14' and 15', 16', respectively. The circuit also comprises a resistor 28' and a stray inductance 29'.

The function of the snubber diode branch connected in parallel with each GTO is as follows: when the first GTO 5' is turned off the voltage thereacross starts to increase, and it would in absence of the snubber diode increase to a comparatively high level when the current therethrough is still high, so that the power losses will be comparatively high. The arrangement of the snubber diode 9' and the capacitor 11' will lead to a lower dU/dt over the GTO 5' upon turning off said GTO, so that the snubber diode is turned on and the capacitor 11' is charged when the voltage is increasing over the GTO 5'. After the turning off state of the GTO 5' the first diode 7' will be turned on and lead the current to the load 4' and the current through the snubber diode 9' will be neglectable. When the GTO 5' is turned on again the capacitor 11' will be discharged comparatively slowly through the diode 10' and the resistor 28' and stray inductance 29', so that it will preferably be empty and ready to be charged again when the GTO 5' is turned off next time. It is essential for protecting the GTO upon turning off thereof that the snubber diode 9' is turned on rapidly, and this is ensured by making the diode of SiC. It may also happen that the GTO 5' is turned on before all the excess charge carriers and all the current has "disappeared" in the snubber diode 9', which means that there will be a reverse recovery current through the snubber diode 9' when the GTO 5' is turned on, but the switching losses resulting therefrom will be very low when the snubber diode is made of SiC.

Fig. 3 shows a parallel connection of two diodes, namely a first small SiC diode 17 and a large diode 18 of Si. According to an embodiment of the invention any of the diodes 7, 8, 7', 8' and the snubber diode 9' may be exchanged for said parallel connection

shown in Fig. 3. This will when the corresponding switching device is turned off mean that the small SiC diode will, due to the low thickness and short charge carrier life time thereof and low forward recovery, take care of a major portion of the current through the two diodes instantaneously upon turning off the switching device, so that there will be substantially no voltage overshoot over the diodes 17 and 18. The portion of the current led through the diode 17 will decrease with time and turn into a minor portion of the current led through the two diodes during the turn off state of the switching device. Accordingly, after a while almost all the current is led through the larger Si diode 18 having a much higher amount of charge carriers. Thus, the parallel connection according to Fig. 3 makes it possible to use a Si diode 18 for conduction when a switching device is turned off without any negative effect upon the power electronic circuit of a high forward recovery thereof. The use of such an arrangement is best suited for applications where the forward recovery is critical but not the reverse recovery, because the large silicon diode 18 will cause a large reverse recovery when turning off. Such applications may specifically be as snubber diodes.

Fig. 4 illustrates a module according to the invention, which comprises a parallel connection of ten switching devices 5" and two diodes 8" of SiC. This module will have the same function as the parallel connection of the first switching device 5 and the second diode 8 in Fig. 1. The gates 19 of the switching devices are interconnected and intended to be actuated simultaneously. The switching devices 5" are intended to conduct equal parts, for instance 50A, of the total current of the module, in that case 500A, to be supplied to a load, while the two diodes 8" are intended to have the same function as the second diode 8 in Fig. 1 and together conduct the current through the load when the switching devices of a similar module not shown and connected to this module are turned off. A first terminal 20 of the module is intended to be connected to a terminal of a power supply, a second terminal 21 of the module is intended to be connected to the switching devices and

diodes of a similar module at the side thereof not connected to the other terminal of said power supply and a third terminal 22 is provided for simultaneously turning the switching devices 5" on and off.

It is illustrated in Fig. 5 how the diodes and switching devices are arranged in a closed casing 23. The back side side of each device chip 5" and 8" is soldered to a conducting plate 24 and by that interconnected. The opposite side of the switching devices 5" and the diodes 8" are interconnected through conducting strips or bonding wires to a conducting bar 25, wherein the strips from the left side row of the switching devices in Fig. 5 to said bar 25 are not shown in the Figure. Furthermore, there is a second conduction bar 26 to which the gates of all the switching devices are connected. The terminals 20, 21 and 22 are indicated in Fig. 5. The chips 5" and 8" are preferably arranged in three rows with four in each row, so that the right hand row in Fig. 5 will have two diodes 8" and two switching devices 5". The conduction plate 24 has cooling channels 27 for cooling the semi-conductor devices of the module, by a medium (liquid or gaseous) flowing therethrough. Thanks to the fact that the diodes 8" are made of SiC switching losses created in said module will be much lower than in prior art circuits of the same type, so that it will be possible to arrange said devices at a high density without any risk of overheating. Although a module constituting half the so called phase leg is described above and illustrated in the figures the invention also comprises alternative device modules of this type. For instance may in one embodiment the entire phase leg in Fig. 1, i.e. all the components 5, 8 and 6,7, be included in the module, which then will consist of the two sets of the kind shown in Fig. 4. It would also be possible to construct the device module to comprise all the three phases of the converter including six such sets or packs.

The invention is of course not in any way restricted to the preferred embodiments described above, but several modifications thereof

will be apparent to a man with ordinary skill in the art without departing from the basic idea of the invention.

Although a converter circuit in the form of an inverter circuit has been shown in the figures, the converter circuit of the invention may just as well be a rectifier or a DC-DC-converter circuit. Furthermore, such circuits may have the most different configurations, and the converter circuits shown in the figures are only some of a very large number of possible converter circuits known in this field and within the scope of the invention.

One or each diode may be integrated into the same chip as the switching device connected antiparallely thereto if they are both or all made of SiC, and it would also be possible to integrate all diodes and switching devices made of SiC in one and the same chip.

Claims

1. A converter circuit having at least one switching device (5, 6, 5', 6',5") and a diode (7, 8, 7', 8', 9', 8", 17) arranged to be conducting when the switching device is turned off and reverse biased when the switching device is turned on, characterized in that the diode is made of SiC.

2. A circuit according to claim 1, characterized in that said diode is a Schottky diode.

3. A circuit according to claim 1 or 2, characterized in that said diode (7, 8, 7', 8', 8") is arranged to, upon turning said switching device (5, 6, 5', 6',5") off , alone take care of substantially all the current to be conducted one of a) to and b) from a load (4,4') connected to the circuit and fed through said switching device in the turned on state thereof.

4. A circuit according to any of claims 1-3, characterized in that said switching device (5, 6, 5', 6',5") is made of a material being conventional within the semiconductor field, such as Si.

5. A circuit according to any of claims 1-4, characterized in that the switching device is made of SiC, and that it comprises a chip into which both the diode and the switching device are integrated.

6. A circuit according to any of claims 1-5, characterized in that said switching device is one of a) an IGBT (5,6,5"), i.e. an Insulated Gate Bipolar Transistor, and b) another BiMOS switching device.

7. A circuit according to any of claims 1-5, characterized in that said switching device is a GTO (5',6'), i. e. a Gate Turn-Off thyristor.

8. A circuit according to any of claims 1-7, characterized in that it is an inverter (DC→AC) circuit.

9. A circuit according to any of claims 1-8, characterized in that it is a rectifier (AC→DC) circuit.

10. A circuit according to any of claims 1-7, characterized in that it is a DC→DC-converter circuit.

11. A circuit according to any of claims 1-10, characterized in that said diode (7,8,7',8') is connected in series with said switching device (5,6,5',6'), and that a common point at the connection of said switching device and said diode is connected to a load (4,4') to be driven by the voltage converted by said circuit.

12. A circuit according to claim 11, characterized in that said switching device(5,6,5',6') and said diode (7,8, 7',8') are connected to a terminal each of a power supply (1), the voltage of which is to be converted by the circuit.

13. A circuit according to claims 8 and 11 or 12, characterized in that it comprises a second diode (8,8') of SiC connected anti-parallel to said first mentioned switching device (5,5') and a second switching device (6,6') connected anti-parallel to the first mentioned diode (7,7'), and that one of a) said first switching device and said first diode and b) said second switching device and said second diode are arranged to take care of the supply of current to and the other from said load (4,4').

14. A circuit according to claim 13, characterized in that said two switching devices (5,5',6,6') and two diodes (7,8,7',8') are arranged to drive one phase of a three-phase current supply to a load (4,4').

15. A circuit according to claim 1, characterized in that the switching device is a GTO (5',6') i. e. a Gate Turn-Off thyristor, and that said SiC-diode is a snubber diode (9) arranged in a branch connected in parallel with said switching device and also including a capacitor (11) connected in series with the snubber diode and ar-

ranged to be charged when the switching device is turned off and discharged when the switching device is turned on.

16. A circuit according to any of claims 1, 2 and 4-15, characterized in that it comprises a second larger diode (18) connected in parallel with said SiC-diode (17), and that the SiC-diode is designed to instantaneously upon turning off the switching device (5,6,5',6',5") take care of a major portion of the current through the two diodes, said portion decreasing with time and turning into a minor portion of the current led through the two diodes during the turn-off state of the switching device.

17. A circuit according to claim 16, characterized in that the larger diode (18) is made of Si.

18. A circuitry having at least one switching device (5, 6, 5', 6',5") and a first diode (18) arranged to be forward biased and conducting when the device switches in one direction, characterized in that a second diode (17) of SiC is connected in parallel with said first diode and designed to instantaneously upon said switching take care of a major portion of the current through the two diodes, said portion decreasing with time and being in the steady conducting state a minor portion of the current led through the two diodes.

19. A circuitry according to claim 18, characterized in that the first diode (18) is made of Si.

20. A device module comprising several switching devices (5") and at least one diode (8") of SiC arranged in a closed casing having terminals (20-22) for connection thereof to an electric circuit.

21. A module according to claim 20, characterized in that it is designed to be arranged in a converter circuit, that it has switching devices (5") connected in parallel and at least one SiC diode (8") connected anti-parallel to the switching devices, and that the gates (19) of the switching devices are connected in groups.

22. A module according to claim 21, characterized in that it comprises means (20,21) for connection thereof to a substantially identical module with one side of the switching devices (5") and diodes (8") of the module connected to the opposite side of the switching devices and diodes of the other module, and that a terminal of each module connected to the switching devices and diodes of the module at the side not connected to the other module is arranged to be connected to one terminal each of a power supply, the voltage of which is to be converted by the circuit.

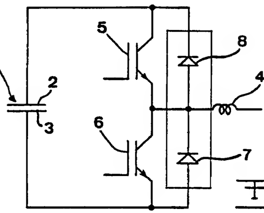


Fig 1

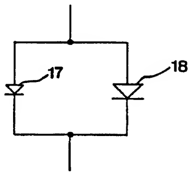


Fig 3

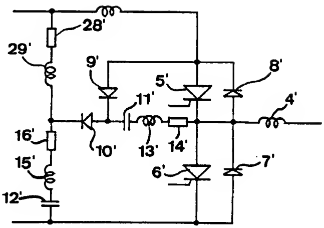


Fig 2

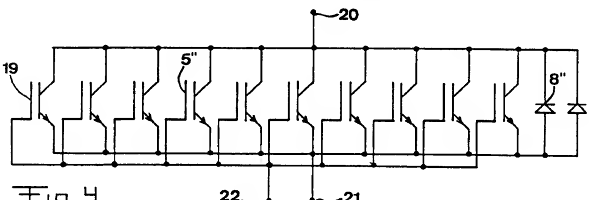


Fig 4

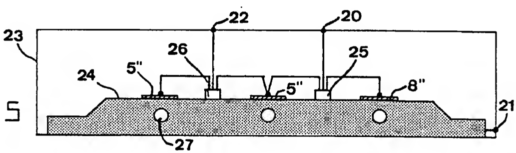


Fig 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 96/00755

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H02M 1/00, H03K 17/08, H02H 7/12
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H02M, H02H, H03K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Kjeld Thornborg, "Power Electronics-in Theory and Practice", 1993, Studentlitteratur, (Lund), page 57 - page 60, especially pag 60 fig. 2.56.	1-15
A		16-19
	--	
Y	WO 90/07192 A1 (CREE RESEARCH, INC.), 28 June 1990 (28.06.90), page 1 - page 8	1-15,20-22
A		16-19
	--	
Y	EP 0533158 A2 (HITACHI, LTD), 24 March 1993 (24.03.93), column 13, line 25 - line 30, figure 13A	20-22
	--	

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 October 1996	22.10.96

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 96/00755

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Patent Abstracts of Japan, Vol 18,No 673, E-1647, abstract of JP,A,6-268202 (FUNAKI, HIDEYUKI), 22 Sept 1994 (22.09.94)	2

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INTERNATIONAL SEARCH REPORT

01/10/96

International application No.
PCT/SE 96/00755

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
WO-A1-	90/07192	28/06/90	NONE		
EP-A2-	0533158	24/03/93	JP-A-	5206449	13/08/93
			US-A-	5459655	17/10/95
			JP-A-	5083947	02/04/93
			ZA-A-	9207163	22/03/93